

# BULLETIN

## OF THE INSTITUTE OF METALS

VOLUME 4

OCTOBER 1958

PART 14

### INSTITUTE NEWS

#### Papers on the Constitution of Alloy Systems

Owing to pressure on space in the Institute's *Journal*, the Publication Committee has decided that papers describing constitutional work on alloy systems shall be printed in summary form. Such papers will consist of the minimum number of diagrams and photomicrographs required to present the new results, together with a brief text pointing out special features of the experimental technique or of the results. In general, tables of heat-treatments, &c., will not be published.

Intending authors of constitutional papers are urged to prepare their MSS. in the required form, as otherwise there will be delay in publication. When submitting MSS. authors should also send a full report of the work concerned for the benefit of the Publication Committee. If the paper is accepted this report will be deposited in the Joint Library for consultation by anyone interested, and a note to this effect will be printed in the paper.

#### Election of Members

The following 11 Ordinary Members, 4 Junior Members, and 1 Student Member were elected on 1 September 1958:

##### *As Ordinary Members*

- BALL, Charles Selwyn, B.Met., Ph.D., A.I.M., Chief Metallurgist, Steel Division, Steel Company of Wales, P.O. Box No. 9, Port Talbot, Glam.
- BOXALL, Derek, A.I.M., Liaison Officer, British Non-Ferrous Metals Research Association, Euston Street, London, N.W.1.
- DWIGHT, Austin Elbert, M.S., Associate Metallurgist, Argonne National Laboratory, Box 299, Lemont, Ill., U.S.A.
- FAIVRE, Professor René, Doct. ès Sc., Professeur à la Faculté de Sciences et Directeur Scientifique de l'Ecole Nationale Supérieure de la Métallurgie et de l'Industrie des Mines, 15 Place Carnot, Nancy, France.
- IMRIE, John, M.Eng., A.M.I.Mech.E., Assistant Works Manager, The Wednesbury Tube Co., Ltd., Bilston, Staffs.
- KINSEY, Norman Frederick, Superintendent, The Harlow Metal Co., Ltd., Edinburgh Way, Harlow, Essex.
- LÜCKE, Professor Kurt, Dipl.phys., Dr.rer.nat., Professor für physikalische Metallurgie, Institut für allgemeine Metallkunde und Metallphysik, Technische Hochschule, Aachen, Germany.
- PARKER, Arthur Ronald Sidney, A.M.I.Mech.E., Metallurgical Engineer, The Manganese Bronze and Brass Co., Ltd., Handford Works, Ipswich.

- PARKIN, George, A.Met., F.R.I.C., F.I.M., Director, Production Development, Mappin and Webb, Ltd., Sheffield 2.
- SCHVARTZ, Pedro, Civil Eng., Consulting Engineer, Alsina 715, Buenos Aires, Argentina.
- YOUNGS, Willard O., B.S., Librarian, Seattle Public Library, 7th and Olive Way, Seattle 1, Wash., U.S.A.

##### *As Junior Members*

- BUTTERY, Terence Clive, B.Sc., A.I.M., Metallurgist, Research Laboratories, Armstrong-Siddeley Motors, Ltd., Parkside, Coventry.
- KIRKAAS, Knut, Siviling., Forsker, Forsvarets Forskningsinstitut, Kjeller pr. Lilleström, Norway.
- SPRIGGS, Paul Humphrey, B.Sc., A.R.C.S., Metallurgical Crystallographer, English Electric Co., Ltd., Whetstone, nr. Leicester.
- SYME, David McDonald, B.Sc., Metallurgist attd. to Welding Group, The Motherwell Bridge and Engineering Co. Ltd., P.O. Box No. 4, Motherwell, Scotland.

##### *As Student Member*

- SPENCER, Russell Dudley, L.I.M., Works Metallurgist, Mallory Metallurgical Products, Ltd., Exhibition Grounds, Wembley, Middx.

#### Opportunities for Qualified Men

Any recently elected member of the Institute of Metals may, on application to the publishers, Croom Helm Press, Ltd., Darley House, 1 Lower James Street, W.1, receive a complimentary copy of the "Directory of Opportunities for Qualified Men, 1958".

### PERSONAL NOTES

MR. J. D. BAIRD has left the A.E.I. Research Laboratory, Aldermaston, to take up an appointment as Senior Government Research Fellow in the Metallurgy Division, National Physical Laboratory.

M. J.-J. BARON has been appointed Directeur, Division des Applications Atomiques, Compagnie Pechiney, Paris.

MR. B. L. DAVIES has been appointed lecturer in metallurgy at the Brunel College of Technology, Acton, London, W.3.

MR. S. H. GELLES has left the Massachusetts Institute of Technology and joined Nuclear Metals, Inc., Cambridge, Mass.



MR. P. GOLDENBAUM has left Langley Alloys, Ltd., and joined the staff of English Electric Co., Ltd., Whetstone, near Leicester.

MR. T. H. HALL has been transferred to the Ministry of Supply Staff, British Joint Services Mission, Washington, D.C.

DR. G. G. HATCH has left the Quebec Iron and Titanium Corporation and is now with W. S. Atkins and Associates, Ltd., Toronto.

DR. T. A. HENDERSON has been appointed Senior Development Metallurgist in the Research and Development Dept. of Head, Wrightson and Co., Ltd., Thornaby-on-Tees.

MR. E. LITTAUER has been awarded the degree of B.Sc. in metallurgy with first-class honours at London University.

MR. ERWIN LOEWY, a director of the Baldwin-Lima-Hamilton Corp., New York, has been presented with a U.S. Air Force Scroll of Appreciation in recognition of his meritorious service to the Force from 1941 to 1957.

DR. J. G. MORRIS has left the Kaiser Aluminum and Chemical Corp. and is now at the Aluminum Technical Center, Olin Mathieson Chemical Corp., New Haven, Conn.

MR. D. A. OLIVER, Director of Research of the B.S.A. Group Research Centre, has been appointed a member of the Steering Committee of the Warren Spring Laboratory of the D.S.I.R.

MR. J. E. PALENTINE has been awarded an honours degree in metallurgy at Sheffield University and has taken up an appointment with the U.K. Atomic Energy Authority at the Research and Development Laboratories, Culcheth.

DR. N. H. POLAKOWSKI has been promoted to the rank of full professor at the Illinois Institute of Technology.

DR. A. L. ROBILLARD is now an engineer in the Service de Radiométallurgie, Centre d'Etudes Nucléaires, Fontenay-aux-Roses (Seine).

DR. J. F. WATSON has left the University of Michigan and is now Senior Research Engineer, Convair Astronautics, San Diego, Calif.

DR. J. L. WHITE has been appointed a staff member of John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corp., San Diego, Calif.

MR. L. L. WYMAN, Chief of the Chemical Metallurgy Section of the National Bureau of Standards, has received the Meritorious Service Award of the U.S. Department of Commerce for his original contributions to alloy theory and to the design and production of important ordnance items.

### Death

The Editor regrets to announce the death of:

MR. FREDERICK HAMILTON KEATING, Head of the Metallurgical Section of the Engineering Research Department, Imperial Chemical Industries, Ltd., Billingham Division, on 16 August.

## LETTERS TO THE EDITOR

### Determining Grain Orientation in F.C.C. Metals by Using Twin-Boundary or Slip-Line Traces on One Surface Only

BARRETT<sup>1</sup> mentions briefly a method of determining grain orientations by using traces of known planes on one surface only. This method always gives pairs of answers, as it cannot distinguish between the true orientation and its mirror image in the exposed surface. However, it is useful in cases where the grain size is too small for the usual X-ray method to be suitable.

The particular example chosen by Barrett to illustrate the method is rather misleading, as traces on two surfaces were used. As Barrett says, three  $\{111\}$  traces on one surface are known, and it is implied that all four  $\langle 111 \rangle$  poles must be arranged to lie on the trace normals—an error not present in the original account.

In general, when only three of the four  $\{111\}$  traces are known, either two or four pairs of solutions exist. The mathematics of this can be understood most readily if one considers only two known  $\{111\}$  traces; then there are an infinite number of solutions and the loci of the other two  $\langle 111 \rangle$  poles can be plotted. This is shown for several angles between known traces in Fig. 1. To avoid overcrowding the diagrams, only one of each pair of loci is drawn; the other can be obtained by rotating the diagram through  $180^\circ$ . A third known  $\{111\}$  trace will give a third diagonal on the stereographic plot; the intersection of this with the loci gives the two or four pairs of solutions. Fig. 1 (f) shows an example of this. If now a fourth  $\{111\}$  trace is known, only one pair of solutions will satisfy the data.

It will be seen from Figs. 1 (a)–(e) that, with three known traces, four pairs of solutions occur only over a limited range of angles between adjacent trace diagonals. With two of the four pairs of solutions, the two  $\langle 111 \rangle$  poles on the chosen diagonals are  $109\frac{1}{2}^\circ$  (i.e.  $2 \tan^{-1} \sqrt{2}$ ) apart. This can happen only when the angle between the trace diagonals is less than  $(180^\circ - 109\frac{1}{2}^\circ) = 70\frac{1}{2}^\circ$ . As any two of the three traces can be taken as the chosen pair, it follows that the angles between either of the chosen traces and third traces must be greater than  $(180^\circ - 2 \times 70\frac{1}{2}^\circ) = 39^\circ$ . Therefore, with three known traces, there will be four pairs of solutions if all angles between adjacent trace diagonals are between  $39^\circ$  and  $70\frac{1}{2}^\circ$ , and two pairs of solutions if any angle is outside this range.

If one of the three twins of the crystal has a further (second-order) twin, then we can select the correct pair of orientations by trying which of the solutions fits the second-order twin trace. This is a more laborious method than with the case of four first-order twin traces, but it occurs more frequently in practice.

When plotted on the unit triangle, the two orientations of a pair are the same, and for some applications there is no need to distinguish between them. In other cases we must be able to select the correct one. In principle, a second surface is necessary to do this. In some of the writer's work on thermally etched surfaces, it was possible to obtain the required information from the sideways deflection of twin traces on crossing scratches in the specimen surface.

It is, of course, not necessary to draw graphs (as in Fig. 1) to orient a grain. The  $\langle 111 \rangle$  poles of a standard projection can be rotated on to the diagonals representing the poles of twin



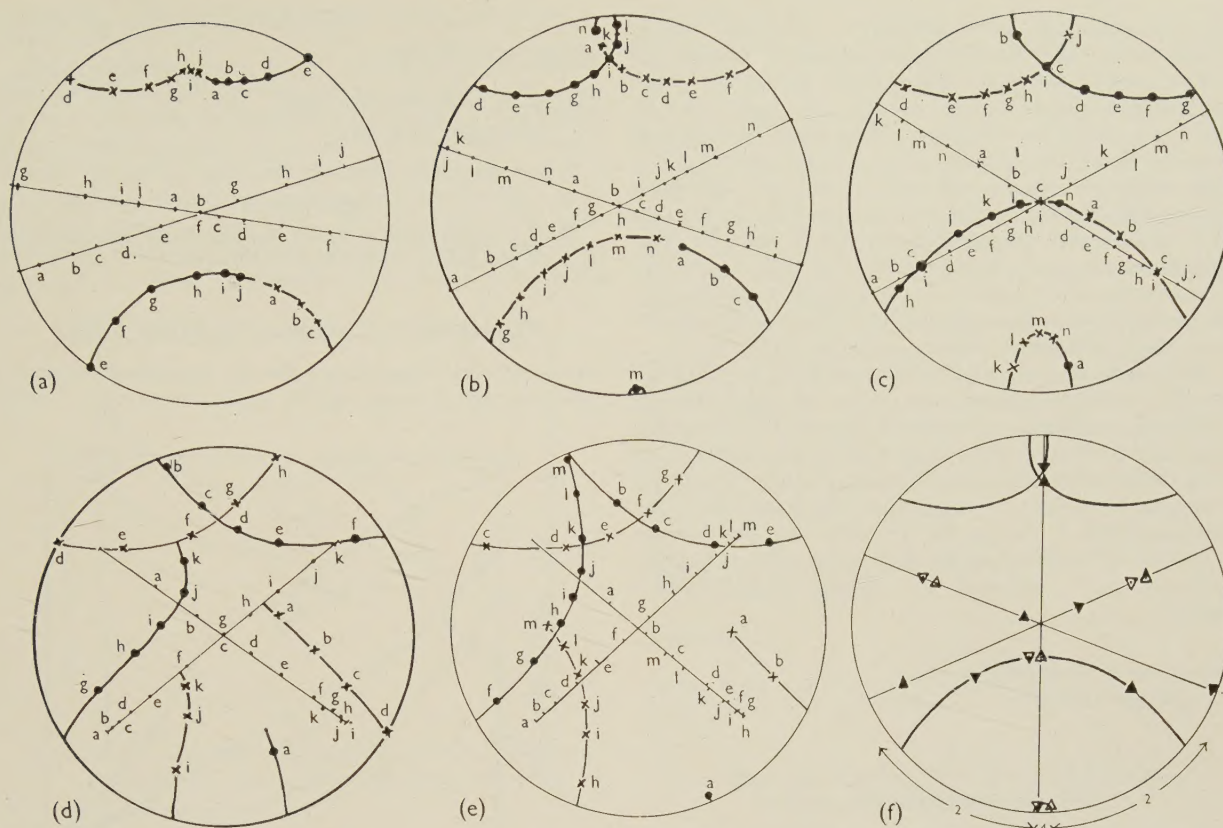


FIG. 1 (a)–(e).—Loci of  $\langle 111 \rangle$  poles with two  $\{111\}$  plane traces known. Inclination of traces: (a)  $26^\circ$ , (b)  $45^\circ$ , (c)  $60^\circ$ , (d)  $75^\circ$ , and (e)  $86^\circ$ . Only one of each pair of loci is shown. The other loci may be obtained by rotating the diagram through  $180^\circ$ .

FIG. 1 (f).—Three known  $\{111\}$  traces. Showing the  $\langle 111 \rangle$  poles of one of each pair of possible orientations. The regions of two and four pairs of solutions are indicated.

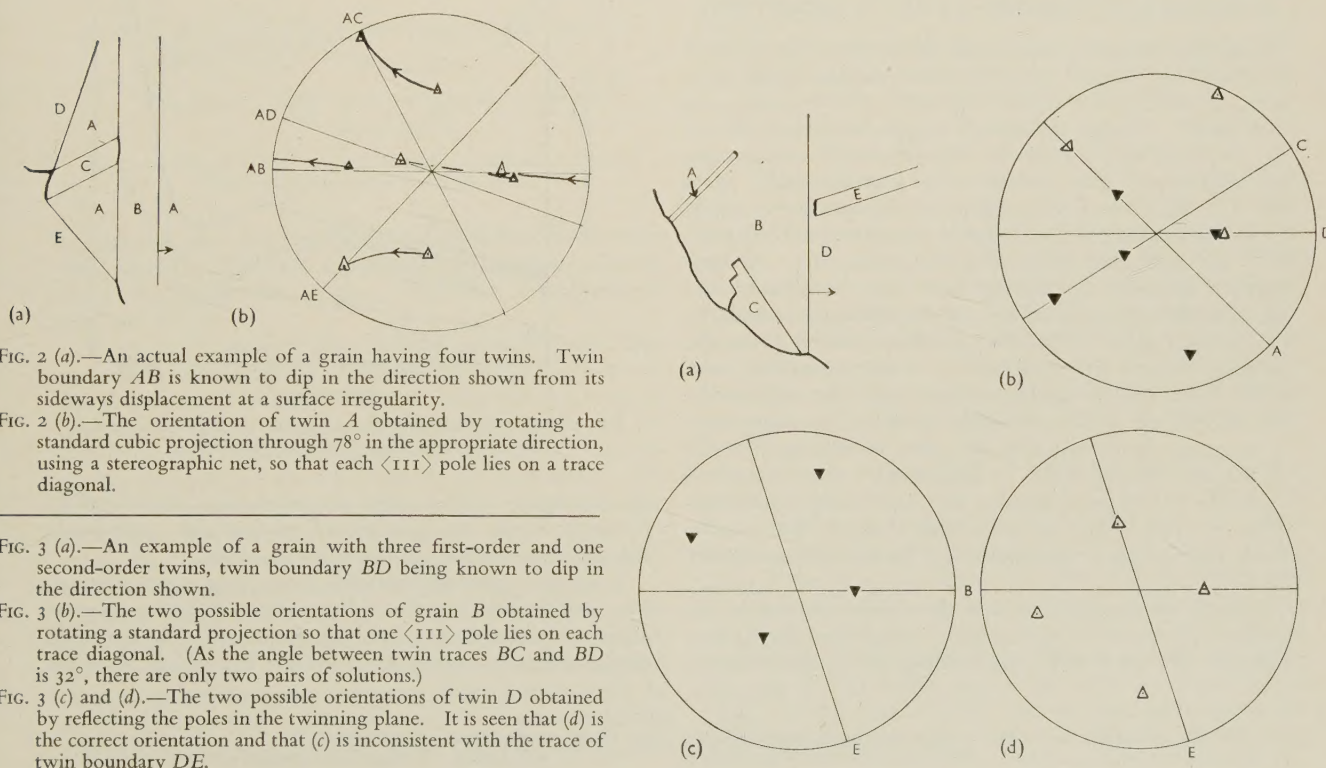


FIG. 2 (a).—An actual example of a grain having four twins. Twin boundary  $AB$  is known to dip in the direction shown from its sideways displacement at a surface irregularity.

FIG. 2 (b).—The orientation of twin  $A$  obtained by rotating the standard cubic projection through  $78^\circ$  in the appropriate direction, using a stereographic net, so that each  $\langle 111 \rangle$  pole lies on a trace diagonal.

FIG. 3 (a).—An example of a grain with three first-order and one second-order twins, twin boundary  $BD$  being known to dip in the direction shown.

FIG. 3 (b).—The two possible orientations of grain  $B$  obtained by rotating a standard projection so that one  $\langle 111 \rangle$  pole lies on each trace diagonal. (As the angle between twin traces  $BC$  and  $BD$  is  $32^\circ$ , there are only two pairs of solutions.)

FIG. 3 (c) and (d).—The two possible orientations of twin  $D$  obtained by reflecting the poles in the twinning plane. It is seen that (d) is the correct orientation and that (c) is inconsistent with the trace of twin boundary  $DE$ .



traces directly, using a stereographic net. This involves selecting the correct azimuth and the correct angle of rotation and is done by trial and error. Fig. 2 shows an example of this for four first-order twin traces and Fig. 3 for three first-order and one second-order twin trace. If the angles between twin traces on the surface are measured to  $\pm \frac{1}{2}^\circ$ , the accuracy of the final orientation may be between  $\pm 1^\circ$  and  $\pm 3^\circ$ , depending on the obliquity with which the trace normal cuts the pole loci. If more than the minimum number of traces are available, this accuracy can be improved. The time required for an orientation determination as shown in Fig. 2 is about  $\frac{1}{2}$  hr; for one as shown in Fig. 3 about 1 hr. Of course the orientations of all twins follow directly, once one is known.

Ambiguities sometimes arise if two twin traces are effectively parallel; while the original grain can be oriented, further information is required to distinguish between the two twins. This can be obtained either from second-order twins or by using the lateral displacement of the twin boundary at a surface irregularity. If there are insufficient twin traces visible and it is permissible to damage the specimen, then slip lines can be produced to supplement the twin traces. However, if the specimen can be damaged, the etch-pit method is often simpler.

H. MYKURA

Department of Natural Philosophy,  
Glasgow University.

#### REFERENCE

1. C. S. Barrett, "Structure of Metals" Second edn., p. 41. 1952: New York and London (McGraw-Hill).

#### Effect of Delay in Quenching on the Micro-structure of a Titanium-2.4 At.-% Nickel Alloy

I HAVE been interested to compare the results of the work of Schofield and Bacon<sup>1</sup> on a quenched titanium-nickel alloy with my own earlier results<sup>2</sup> referred to by the authors in their letter. Though the delayed quench has clearly affected the structures shown by these authors (notably in increasing the amount of  $\alpha$  phase present in the specimen held  $\frac{1}{4}$  hr. at  $835^\circ\text{C}$ .), the more striking differences between the results of a very rapid quench and of a delayed quench such as I observed, have not apparently occurred in the present case. In other systems, however, my findings have been confirmed,\* and we must therefore seek reasons for the difference apparent in the present results. A possible contributory factor is that the holding times at  $835^\circ$  and  $840^\circ\text{C}$ . before quenching were rather short, and the holding temperatures were higher than that used in my work. Probably the most important factor is, however, the difference in the purity of the titanium used in the two investigations. I understand<sup>†</sup> that quite small quantities of oxygen (certainly less than would harden titanium to 150 D.P.H.) can have quite marked effects on the mode and amount of precipitation in quenched titanium-rich alloys.

I would be most interested to see results obtained by the authors' equipment using an alloy made from high-purity titanium (say 70 D.P.H.) and holding the specimens for at

least  $\frac{1}{2}$  hr. at  $820^\circ\text{C}$ . before the instantaneous and delayed quenching treatments.

A. D. McQUILLAN

Department of Physical Metallurgy,  
Birmingham University.

#### REFERENCES

1. T. H. Schofield and A. E. Bacon, *Bull. Inst. Metals*, 1958, 4, (13), 92.
2. A. D. McQuillan, *J. Inst. Metals*, 1953-54, 82, 47.

#### Properties of Titanium-Niobium Alloys

PREVIOUS work<sup>1,2</sup> has shown that the strength of titanium  $\alpha$  solid solutions decreases rapidly as the temperature increases

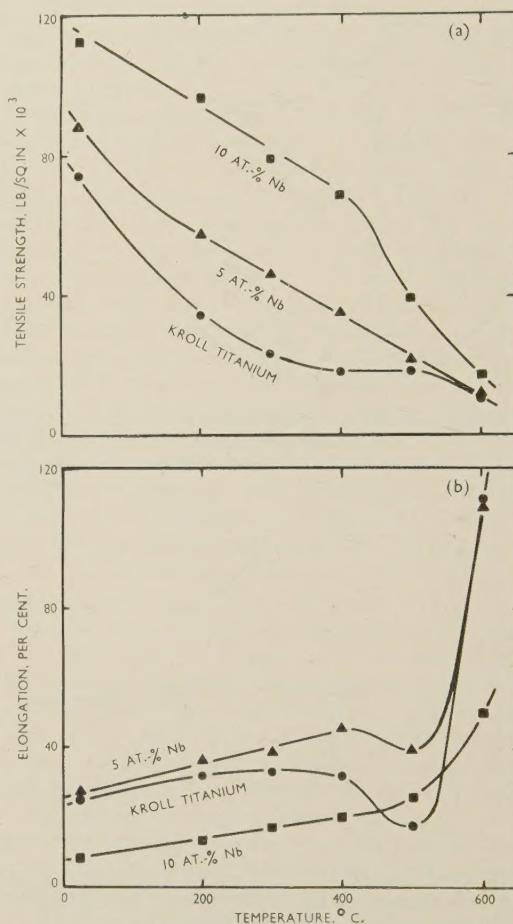


FIG. 1 (a) and (b).—Mechanical properties of titanium-niobium alloys containing 0-10 at.-% niobium.

above  $500^\circ\text{C}$ . The strength at temperatures above  $500^\circ\text{C}$ . is unaffected by the presence of intermetallic compounds, although it is increased at lower temperatures.

A series of titanium-niobium alloys, ranging in structure from single-phase  $\alpha$ , through a series of duplex ( $\alpha + \beta$ ) alloys, to single-phase  $\beta$ , has been examined. The materials, preparation and testing of specimens have been described

\* See, for example, the work on titanium-manganese alloys by H. Margolin reported in a lecture to the New York University Course

on Titanium Metallurgy, September 1957.

† M. K. McQuillan. Private communication.



previously.<sup>1</sup> All specimens were annealed for 16 hr. at 650° C. before testing.

Alloys containing 0, 5, 10, 20, 30, and 50 at.-% niobium were examined, and their properties as functions of the temperature of testing are shown in Figs. 1 and 2. The single-phase ( $\alpha$ ) alloy, marked 0 at.-% niobium, is the basis titanium, and its properties have been discussed previously.<sup>1</sup> The 5 at.-% niobium alloy has a duplex structure, consisting mainly of  $\alpha$  with a small amount of  $\beta$ . The properties of this alloy are similar to those of the basis titanium, except in the range 400°–500° C. Here the strength continues to decrease as the

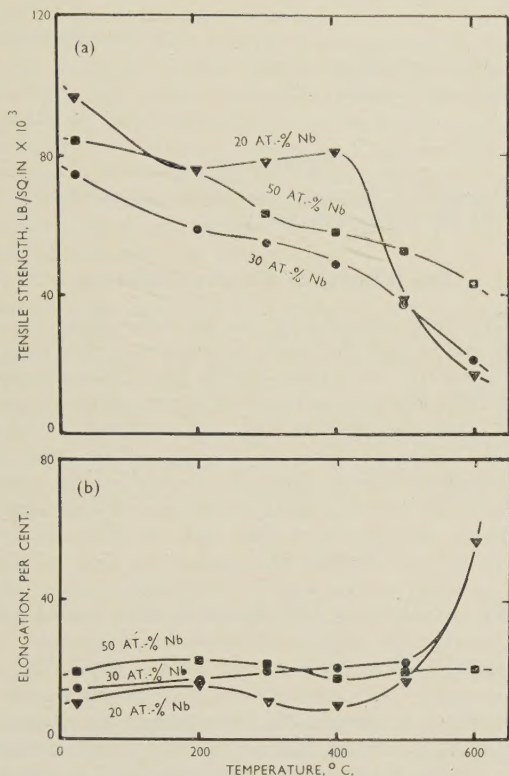


FIG. 2 (a) and (b).—Mechanical properties of titanium–niobium alloys containing 20–50 at.-% niobium.

temperature increases, and the elongation to fracture decreases only slightly. Although appreciable at lower temperatures, the strengthening effect of the second phase is negligible at 500° and 600° C.

The 10 at.-% niobium alloy contains relatively more  $\beta$  than the 5 at.-% niobium alloy, and this is reflected by a change in the properties. The marked strengthening that occurs up to 400° C. is rapidly reduced at higher temperatures, and the elongation to fracture increases to only 50% at 600° C. compared with 110% for the 0 and 5 at.-% niobium alloys. The strength at room temperature of the 20 at.-% niobium alloy is less than that of the 10 at.-% niobium alloy. At 400° C. the position is reversed, although the strength of the 20 at.-% niobium alloy decreases rapidly at higher temperatures.

The 30 at.-% niobium alloy is still in the ( $\alpha + \beta$ ) phase field, although its properties are similar to those of the 50 at.-% niobium alloy, which consists entirely of the  $\beta$  phase. The greater solid-solution hardening of the  $\beta$  phase in the 50 at.-% niobium alloy apparently exceeds the strengthening effect of a duplex structure in the 30 at.-% niobium alloy, with

the result that the 50 at.-% niobium alloy is slightly stronger at all temperatures. Although the strength/temperature curves for the 30 and 50 at.-% niobium alloys are similar in shape, the ductility characteristics of the two alloys vary in that the elongation to fracture of the 50 at.-% niobium alloy does not increase markedly between 500° and 600° C.

These results show that the presence of a second phase ( $\beta$  solid solution) does not affect the strength of titanium alloys at temperatures above 500° C., although considerable strengthening may occur at lower temperatures. This is similar to the result previously obtained for titanium alloys containing an intermetallic compound.

**Acknowledgements.**—The investigation formed part of the programme of research of the Physical Metallurgy Section of the Commonwealth Scientific and Industrial Research Organization, Australia. The work was carried out at the Baillieu Laboratory, University of Melbourne under the general direction of Professors H. W. Worner and J. Neill Greenwood, to whom the author expresses his thanks. The United States Bureau of Mines kindly supplied the commercial titanium.

J. W. SUITER

Physical Metallurgy Section, C.S.I.R.O.,  
Melbourne University.

#### REFERENCES

1. J. W. Suiter, *J. Inst. Metals*, 1954–55, **83**, 460.
2. J. W. Suiter, *ibid.*, 1955–56, **84**, 81.

#### Electron-Optical Study of Ageing in Aluminium–4% Copper Alloy

THOMAS and Nutting<sup>1</sup> and Koda and Takeyama<sup>2</sup> have obtained some important results on the interaction of dislocations and precipitates which is the crux of the age-hardening problem. However, the oxide replica is limited in resolution and gives little information on the nature of the precipitate/matrix interface. I have been able to prepare thin metal foils from an aluminium–4% copper alloy, aged in the bulk condition, and to examine them in a Siemens Elmiskop 1, by which a resolution better than 10 Å. can be obtained.

The precipitate mainly responsible for the hardening of aluminium–copper alloys at low ageing temperatures is G.P. [2]. This is thought to be coherent with the matrix, but it has a tetragonal structure with a lattice parameter less than that of aluminium in a direction normal to the precipitate platelet. Thus the aluminium lattice near the faces of the precipitate is distorted to give an induced tetragonality instead of the normal cubic structure. It is difficult to predict the precise contrast effects when such a strained region is examined in the electron microscope. However, it is clear that the diffracted intensity from a column of crystal containing either a precipitate or its adjacent strain field will be different from that of a perfect column of crystal.

Fig. 1 (a) is a micrograph of a thin foil prepared from a specimen aged for 1 day at 130° C. Electron diffraction shows that the precipitates are very small G.P. [2] zones. They are only about 6 Å. wide and 150 Å. in diameter. Near many of the precipitates there is a region of dark contrast, and it is suggested that this represents a strained region in the matrix which arises from the tetragonality of the coherent G.P. [2] precipitates. The contrast effects are very sensitive to orientation and are not visible around the other set of precipitates which are not quite vertical. As the precipitates grow the strain fields become larger, and eventually the whole of the



matrix is strained. In this condition a high stress is required to force a dislocation through the alloy, and it is suggested that this is responsible for the hardness of alloys containing coherent precipitates.

At temperatures where G.P. [1] and G.P. [2] are formed, the precipitation of  $\theta'$  is always associated with a general softening of the alloy. The  $\theta'$  precipitate is thought to be only partially coherent. The lattice misfit at the interface is absorbed by a van der Merwe cross-grid of dislocations and the interface strain is very localized. Fig. 1 (b) is a micrograph of a thin

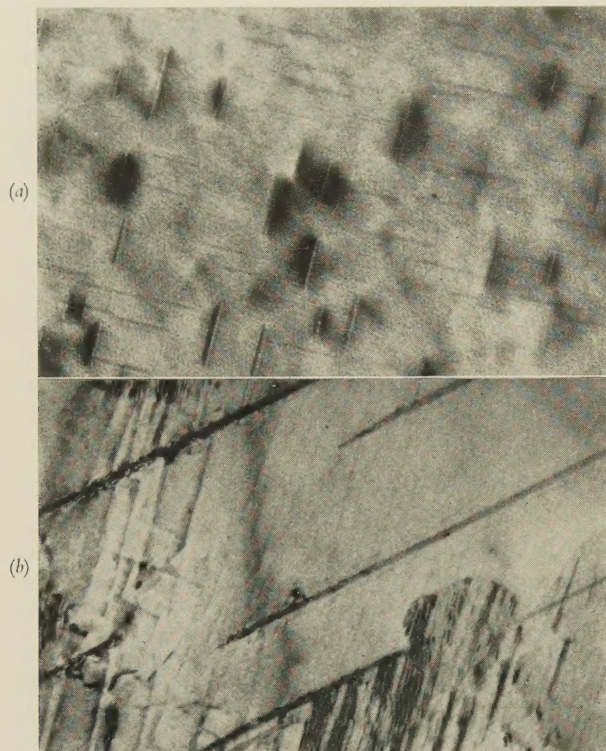


FIG. 1.—Thin foil of aluminium-4% copper alloy. (a) Aged 1 day at 130° C.  $\times 300,000$ . (b) Aged 1 day at 200° C.  $\times 50,000$ .

foil prepared from a specimen aged for 1 day at 200° C. The surface orientation is approximately (100) and all three orientations of  $\theta'$  are visible. Two sets of plates are vertical and appear as needles, while the third is horizontal and is visible on account of the moiré pattern formed by the superposition of two lattices of different lattice parameters. The fringes of the moiré pattern are in fact identical with one set of the cross-grid of dislocations at the interface. It is apparent that a small part of the interface is still coherent and that the vertical  $\theta'$  plates have interfered with the growth of the horizontal plate. No strain field is ever visible near the vertical  $\theta'$  plates. This is to be expected as the strain due to the cross-grid of dislocations is localized at the interface. Thus there is no obstacle to slip in the matrix and several dislocation traces are visible in Fig. 1 (b). It is clear that some pass right through the  $\theta'$  plates with only a slight lateral displacement. This observation supports the results of Thomas and Nutting and Koda and Takeyama and can be explained in two ways. A dislocation may glide up to the plate, move through it on another slip system, and glide away on the other side. (From the traces in the matrix it is clear that cross-slip is possible in these alloys.) On the other hand, a dislocation may glide up to the

interface and activate a dislocation on the other side of the plate. This would be analogous to induced slip at a grain boundary. In either case the stress required cannot be very great, as the stress which is generated in the foil by the heating effect of the electron beam is quite low.

These results show that in aluminium-copper alloys at any rate, the hardening effect of the precipitate is determined not by the precipitate itself but by its associated strain field. Thus the large coherency strains associated with the G.P. [2] precipitate greatly increase the stress required to move a dislocation through the lattice, whereas the small local strains at the boundary of a  $\theta'$  precipitate are a comparatively minor obstacle.

R. B. NICHOLSON

Department of Metallurgy,  
Cambridge University.

#### REFERENCES

1. G. Thomas and J. Nutting, *J. Inst. Metals*, 1957-58, **86**, 7.
2. S. Koda and T. Takeyama, *ibid.*, p. 277.

#### The Thorium-Cerium System

WE were most interested to see the letter from Dr. van Vucht,<sup>1</sup> and to read the paper on thorium-cerium alloys to which he refers.<sup>2</sup> We cannot entirely agree that we neglected the possibility that the minimum in the curve of lattice spacing plotted against composition (Fig. 2 of our paper<sup>3</sup>) might be due to the combined effects of "scavenging" by cerium, and alteration of the thorium lattice by cerium in solid solution. We did, in fact, speculate about the removal of some impurity by cerium, and concluded that such an effect should be apparent only for the first few atomic per cent. of cerium added, as stated in our paper. The lattice spacings of the alloys do not, however, begin to rise towards that of cerium until a considerable addition of cerium has been made. The last paragraph of our paper was intended to imply that, even if "scavenging" were taking place, it could not account for the persistence of abnormally low spacings up to approximately 30 at.-% cerium, which is the theoretically interesting point. Dr. van Vucht appears to agree that the "scavenging" action would be confined to low cerium contents.

The main point of difference in detail between Dr. van Vucht's work and our own concerns the initial sharp fall in the lattice-spacing/composition curve up to about 1.4 at.-% cerium, which we observed for our own particular sample of thorium, but which was not evident in Dr. van Vucht's experiments. It is to be noted that he examined no alloys with less than 15.1 at.-% cerium, and so must be unaware of the effect of small cerium additions on the lattice spacings of his own sample of thorium. His criticism is really based only on the observation of a lower lattice spacing for thorium than we obtained. In this connection, it should be noted that the thorium used by James and Straumanis<sup>4</sup> contained 1% of metallic impurity; Chiotti,<sup>5</sup> working with thorium reported to contain only 0.12% of metallic impurity, obtained a significantly higher lattice spacing (5.079 kX as opposed to 5.074 kX). Our own major metallic impurity was 0.02% calcium. The spacing value reported in our paper (5.082 kX) agrees reasonably well with the value of 5.0785 kX obtained recently for iodide thorium by Mr. D. S. Evans in our own laboratory, after annealing for 1 hr. at 750° C. in a thoroughly outgassed and evacuated silica capillary. Differences between the lattice spacings observed for different samples of thorium



are not unexpected, and in our opinion the situation with regard to the spacing of pure thorium is insufficiently understood to justify empirical calculations of the type reported by Dr. van Vucht.

Dr. van Vucht has, we think, been misled by our statement that very faint lines due to  $\text{CeH}_2$  were observed into assuming the existence of about 3 at.-% hydrogen in our thorium. It was not our intention to imply that the source of the hydrogen was the thorium. The lines were present in films of unalloyed cerium, and we are strongly of the opinion that the hydride was formed, during the annealing of the filings, by reaction with traces of water vapour released from the inner surfaces of the Pyrex tubes in which the strain-relief anneal was carried out.<sup>6</sup> This opinion is strengthened by the fact that the intensities of the hydride lines observed in early experiments were greatly reduced by greater attention to the outgassing of the Pyrex tubes before their use in annealing experiments. In the case of cerium itself the use of filaments, which have a smaller specific surface than filings, also greatly reduced the intensity of the hydride pattern. In the films from which the results reported in our paper were obtained, the hydride intensity was very low indeed.

We have no evidence that hydrogen was present in our massive thorium after annealing *in vacuo* ( $10^{-6}$  mm. Hg) for several days at  $800^\circ\text{C}$ . before making filings in an atmosphere of purified argon. Though a small pick-up of hydrogen could possibly have occurred during strain-relief annealing of the filings, it could hardly have reached 3 at.-% (about 2.5 c.c./g.) under our conditions. If such pick-up occurred to any serious extent, whether alone or in addition to an initial hydrogen contamination, it would not be expected to be

uniform from experiment to experiment. This would have led to erratic results, of which we found no evidence. We are further able to say that when lanthanum is alloyed with thorium, from the same source and under the same conditions as before, no sharp decrease of lattice spacing occurs on addition of the first few atomic per cent., in spite of the stability of lanthanum hydride. Instead, there is an almost linear increase of lattice spacing in thorium-rich alloys.

We feel it is unlikely that the sharp drop in lattice spacing on the initial addition of cerium to our thorium is due to the reaction of the solute with hydrogen present in the thorium, but we do not rule out entirely the possibility of some sort of scavenging action on some other impurity.

We agree with Dr. van Vucht that, if  $\delta\text{-Ce}$  is body-centred cubic, a continuous series of body-centred cubic solid solutions might be expected at the higher temperatures, but there is no evidence to our knowledge in support of this speculation.

R. T. WEINER

W. E. FREETH

G. V. RAYNOR

Department of Physical Metallurgy,  
Birmingham University.

#### REFERENCES

1. J. H. N. van Vucht, *Bull. Inst. Metals*, 1958, **4**, 94.
2. J. H. N. van Vucht, *Philips Research Rep.*, 1957, **12**, 351.
3. R. T. Weiner, W. E. Freeth, and G. V. Raynor, *J. Inst. Metals*, 1957-58, **86**, 185.
4. W. J. James and M. E. Straumanis, *Acta Cryst.*, 1956, **9**, 376.
5. P. Chiotti, *J. Electrochem. Soc.*, 1954, **101**, 567.
6. B. J. Todd, *J. Appl. Physics*, 1955, **26**, 1238.

## FUEL EFFICIENCY IN THE MELTING AND THERMAL TREATMENT OF METALS B18

*A one-day informal discussion on "Fuel Efficiency in the Melting and Thermal Treatment of Metals" was held under the auspices of the Metallurgical Engineering Committee at the College of Technology, Gosta Green, Birmingham, on 26 February 1958. Professor H. Ford, Chairman of the Committee, occupied the Chair.*

*A summary of the proceedings, prepared by Mr. D. Boxall, is given below.*

### Introductory Papers

INTRODUCTORY papers were presented by Mr. F. C. ASHEN (Imperial Chemical Industries, Ltd., Metals Division) and Mr. P. F. HANCOCK (Birlec, Ltd.).

Mr. ASHEN, who dealt mainly with oil- and gas-fired furnaces, said that it was essential nowadays for furnaces to be sited in the production flow line. For this reason, as well as others, solid fuel had been almost completely replaced by gas, oil, and electricity. However, an overall view of fuel efficiency would include the conversion efficiencies of these fuels, a lesson brought home to the nation during the last war. We should be dissatisfied with present performances, as in most cases improved fuel efficiencies could be obtained.

Assessment of our state of fuel economy was difficult. It was rare for individual processes to be separately metered, and even when this was done the complex data needed expert analysis before recommendations could be made to management.

Electricity was ideal for induction melting furnaces and for heat-treatment when close temperature control was required,

or where contact with combustion products was undesirable. Under other conditions the use of electricity was probably wasteful, and oil or gas was preferred.

The scope of gas and oil heating had been extended recently by high-velocity burner developments. Using these nozzle-jet burners, streams of high-velocity gases were injected into the furnace, and combustion was virtually flameless. Under these conditions radiation by gas molecules was an important mode of heat transfer. Triatomic molecules, such as  $\text{CO}_2$ , radiated more intensely than diatomic ones, and rapid complete combustion was desirable.

Industrial gas was now almost entirely town gas, producer-gas plants having been eliminated by the increasing cost of anthracite and coke. Producer gas, however, was useful for low-temperature heating because of the enhanced heat diffusion caused by rapid mixing of air and gas in injection burners. In modern furnaces using town gas, direct contact between work and products of combustion was common, except for the susceptible aluminium alloys. Efficient heat transfer was thus ensured and a protective atmosphere created. Several conversions of large furnaces to concentrated-combustion gas



burners had given rise to improved thermal efficiencies of about 50%. (Details of these conversions were given by Mr. Ashen.)

In oil firing the choice of oil was governed by the scale of operation. Heavy oils and creosote pitch needed special handling equipment, but because of their more luminous flames they gave higher efficiencies in large reverberatory melting furnaces, justifying the extra cost. Light oils were useful for gravity-fed burners to heat small pots, where the less luminous flame minimized the effect of flame impingement. Medium oils were useful for intermediate annealing and preheating on medium-scale operation. The carbon : hydrogen ratio was a guide to the character of the flame to be expected from an oil. Carbon represented about 85% in petroleum residual fuel oils, with hydrogen varying from 10.5% in the heavy to 13% in the lighter oils. Tar oils, however, in the equivalent heavy grade contained 89% carbon and 6.5% hydrogen. This wider ratio gave brighter luminosity to the flame with better efficiency in high-temperature operations.

Careful study of the laws governing heat transfer was essential if higher efficiencies were to be obtained. Besides the application of the well-known laws and the empirical data to furnace design, consideration of flame characteristics would be profitable. The transfer of heat from the furnace into the charge had not been studied as closely as heat loss from the furnace. Empirical figures in pounds of metal per square foot of hearth were used in the past for furnace design. Heat-transfer experiments had shown that much more rapid throughputs could be obtained. For example, 5-in. dia. brass extrusion billets were raised to 760° C. in 20 min. in a gas-fired furnace having concentrated-combustion burners. Furnace output was 1 ton/hr. and overall efficiency was 48%. Further details of improved heating furnaces for a variety of metallurgical operations were then given. In all cases the efficiencies were about 50%.

Discussing the ordering of new equipment, Mr. Ashen said that prior agreement between user and furnace maker about throughput rates and fuel consumption was essential. Furnace manufacturers now quoted performance figures related to fuel consumption. Although good by present-day standards, these often indicated very low thermal efficiencies. Users should be more dissatisfied and examine the thermal losses critically in order to encourage improvements. Standards asked for and obtained, all with above 50% efficiency for normal operating conditions, were:

Through-put, tons/hr.	Furnace	Product	Temp., ° C.	Gas Con- sumption, ft. <sup>3</sup> /ton
10	Continuous	Brass rolling slabs	750	1340
2	"	Copper tubes	650	1500
8	Rotary	" billets	900	1350
3	Batch	" tubes	600	1650

Mr. HANCOCK, who dealt with electric furnaces, said that the conversion efficiency for modern power stations was between 21 and 31%. Electricity costs were not increasing as rapidly as those of other fuels, and nuclear power might lower the cost in the future.

Fuel efficiency could be expressed as:

$$\frac{\text{Heat content of material}}{\text{Total heat in fuel employed}} \times 100.$$

Heat exchange between new and treated charges was the only recuperation possible in electric furnaces, and was usually

inconvenient. This might be worthwhile with continuous furnaces, in which a saving of up to 35% was possible by using counter-flow methods, but not with batch furnaces, where the potential saving was less than 10%. Minimizing the losses was therefore the best way to increase efficiency.

Little could be done about electrical losses, the permitted losses in components being stated in British Standards. Such losses could vary between negligibly small in a mains resistor furnace and very high in an induction heater for aluminium billets, in which the coil losses could be up to two-fifths of the total consumption. Losses from water-cooling vulnerable parts such as fan bearings had to be accepted to avoid frequent maintenance. Well-fitted doors were very desirable. Conveyors and similar parts should have the minimum mass possible. Furnace-wall losses could be kept low by good design. Heavy insulation was needed for fixed-temperature continuous furnaces, but for intermittent or cycling operation a low heat content in the walls was essential. Heat for controlled atmospheres in electric furnaces employed about 1 kWh./100 ft.<sup>3</sup>/100° C. rise in temperature, and could be minimized by good design.

Mr. Hancock then gave a detailed analysis of the performance of a number of electric furnaces for heat-treatment and melting in the ferrous and non-ferrous industries. Efficiencies ranged from 50 to 80%. Fuel efficiency was not an end in itself, but had to be considered in relation to other costs.

Some of the more outstanding points which arose in the interesting discussion which followed are summarized below.

### Refractories

Important factors in increasing thermal efficiency were the design of the furnace lining and the choice of refractory. Insulating refractory could be used to reduce the heat content of the furnace walls in intermittently operated furnaces. For an internal surface of 20 ft.<sup>2</sup>, 13 in. of firebrick with 4½ in. of insulation required 18.6 B.Th.U. for 10 hr. at 1000° C., whereas 6 in. of insulating refractory required only 2.8 B.Th.U. Even if the furnace temperature did not fall to room temperature before reloading, there was a considerable economy.

A permeable refractory had been used in twenty-one furnaces of special design in which the furnace gases were made to leave by passing through the refractory wall into a cavity. Heat given up by the gas reduced the radiant-heat losses. Difficulties in obtaining suitable permeable refractories had prevented further manufacture, although the design was successful.

On the other hand, the permeability of insulating refractories was claimed by some speakers to have caused difficulties in forced-air convection furnaces for low-temperature heat-treatment. Heat transfer here was proportional to the velocity of the gases. Velocities of about 70 ft./sec. were now being used, and the pressure exerted caused some of the furnace atmosphere to pass through the walls, giving a convection as well as a conduction loss. In some cases external wall temperatures up to 200° C. had been experienced. The older types of refractory backed with insulation prevented the gases passing through, and reverting to this type of lining had overcome the trouble. Alternatively, a layer of impervious material such as asbestos could be used with the insulating refractory. Metal walls were also an alternative, but gave losses by conduction at fixing points and trouble from distortion.



### Methods of Control

Badly adjusted separate control cocks for air and fuel were a frequent source of waste. Many speakers emphasized their preference for automatic control equipment which did not need adjustment by an operator. High/low control was satisfactory for ordinary billet-heating furnaces. In the foundry, holding furnaces using small burners could be operated satisfactorily with simple on/off control, but melting furnaces with large burners required high/low control; otherwise excessive melt temperatures were reached because of the residual heat in the lining. On/off control was usually adequate for electric melting furnaces.

Modulating control was more expensive, but had an advantage where protective atmospheres were used in heat-treatment furnaces, because coarser control methods could cause fluctuations in the type of atmosphere.

Slight positive pressure was usually preferred in the furnace, and this needed to be a little greater in controlled-atmosphere heat-treatment furnaces. Losses at the door might lower the thermal efficiency if the furnace was recuperated, but not if the flue gases were leaving at high temperatures.

Pressure control applied to open-hearth aluminium-melting furnaces had given economies which were greatest in the holding period before tapping. Slight positive pressure increased radiation and prevented ingress of cold air.

### Burners

It was generally agreed that developments in burner design had led to higher efficiencies. Fitting air/gas proportioning to the burners of a furnace heating brass slugs to 850° C. had reduced gas consumption from 7 to 3 ft.<sup>3</sup>/lb. of metal. On several types of gas-fired melting and holding furnaces for aluminium alloys, changing to these burners and to insulated refractory linings had given fuel savings of about 60%.

Self-proportioning oil burners were ideal for low-temperature work, but they prevented the use of air preheat in high-temperature applications because of the danger of carbonization and the difficulty of keeping a constant pressure with changing air temperature.

The recently developed jet burner, similar to the concentrated-combustion burner but having a converging instead of a parallel tunnel, had given heat releases of 160 million B.Th.U./ft.<sup>3</sup> of combustion space and velocities of 1800 ft./sec. Although applications had not so far included furnace heating in this country, its possibilities for this use were being examined. It had been used for furnaces in America.

Air preheat was not usually employed with jet or concentrated-combustion burners. There was difficulty in finding refractories to stand up to the conditions, which were made even more severe if preheated air was used. Fused zirconium oxides and fused alumina showed promise. Zirconium silicate had also been used, though it tended to spall. It was reported that sintered rings had been used successfully for a tunnel burner for methane/acetylene, the methane/oxygen mixture being preheated to 500° C. Working temperatures here were 1800°–2000° C.

Mullite was widely used for other burners and gave a good life.

The oil gasifier developed in France, in which a gaseous

mixture was obtained from oil, had been used on the Continent for some non-ferrous work, notably aluminium melting, and had many advantages. Control of combustion conditions was easier than with direct oil firing, and a reducing atmosphere could be obtained if required.

### Recuperation

The use of recuperators in which the heat of the flue gases was used to preheat the air for the burners could provide considerable savings—20% at 400° C. increasing to 30% at 600° C. Metal recuperators were used for air preheat temperatures up to 600° C. and refractory at higher temperatures. Heat recovery by recuperation would not compensate for an inefficient design of furnace.

### Thermocouple Sheaths

Many speakers emphasized the need for improved thermocouple-sheath materials in aluminium-melting furnaces both for normal use and for automatic control. A moderate life was obtained with stainless steel, nickel chrome, mechnite, or cast iron, if a refractory wash was given frequently. Refractory sheaths failed by thermal shock or mechanical damage, although siting in the corner of the bath of a low-frequency induction furnace had been fairly successful. An alternative was to embed the couple in the refractory wall of the furnace almost through to the bath, but special calibration was then needed.

Thick refractory tubes cracked by thermal stressing unless heated before insertion into the melt. In addition, the response time was slow. Thermal stresses were reduced and a more rapid response achieved by using a thin tube, but failure by mechanical damage occurred. A thin mullite tube with a closed end inside an open-ended silicon carbide tube was fairly robust and the response was rapid.

### Melting Losses

A furnace survey\* made recently by the British Non-Ferrous Metals Research Association for the Association of Bronze and Brass Founders of twenty-one foundries producing copper alloys with various types of melting furnace, showed that full utilization of the plant was a major factor in reducing running costs. Obviously, production requirements would not allow furnaces to be operated all the time, but in many cases considerable improvement could be made. Cost data for different types of furnace using different fuels had been obtained, and tables summarizing the main results were shown. The fuels included pulverized coal used by one plant operating with a very low fuel cost. Pulverized coal was available in the particular area concerned.

Special attention was paid to melting losses, because the gain from using a furnace with a low fuel consumption could be completely offset by an excessive melting loss. It could be kept down to 3% in open-flame furnaces by using a flux cover. Melting losses for electric furnaces could be as low as in the best crucible-furnace practice.

\* A report of the survey is available free of charge to B.N.F.M.R.A. and A.B.B.F. members, and can be purchased by others interested direct from the A.B.B.F., 69 Harborne Road, Birmingham 15.



## OTHER NEWS

**International Convention on Transistors and Associated Semi-Conductor Devices**

The Institution of Electrical Engineers is organizing an International Convention on Transistors and Associated Semi-Conductor Devices to be held in London on 25-29 May 1959.

The probable range of subject matter covers materials, basic theory, characteristics and their measurement, transistors as a circuit element, technology and design and manufacture, and applications.

The submission of papers for consideration for inclusion in the Convention is invited. MSS. should be sent in triplicate not later than 30 November 1958. Authors intending to submit papers should also send, as soon as possible, for the guidance of the Organizing Committee, a short summary of each paper of about 200 words.

Further details may be obtained from the Secretary, Institution of Electrical Engineers, Savoy Place, London, W.C.2.

**1959 Nuclear Congress**

The 1959 Nuclear Congress will be held at Cleveland, Ohio, on 5-9 April 1959. The four component sections of the Congress will appeal to engineers, scientists, industrial executives, research workers, and manufacturers and users of peace-time nuclear devices.

To be held at the Cleveland Auditorium, the Congress will be sponsored by over 30 leading engineering, scientific, and management groups and will be open to any interested persons from the United States or abroad. The theme of the Congress will be "For Mankind's Progress".

The Congress includes the Nuclear Engineering and Science Conference, at which over 150 papers will be presented covering such fields as reactor design, disposal of radioactive wastes, radiation shielding, and instrumentation. The Seventh Atomic Energy in Management Conference will outline new developments of importance to industry and their impact on executive decisions. A third portion, the Seventh Hot Laboratories and Equipment Conference, will cover techniques and devices useful in laboratories handling radioactive materials. Concurrent with the technical sessions the "Atomfair" will be held, an exposition at which manufacturers of equipment used in the nuclear field will display their recent developments.

Further information on the Congress may be obtained from the co-ordinating body: Engineers Joint Council, 29 West 39th Street, New York 18, N.Y.

**"Ternary Systems in Metallurgy"**

A course of eight tutorials on "Ternary Systems in Metallurgy" is to be given by Mr. F. B. Elliott at the Northampton Polytechnic of Advanced Technology, St. John Street, London, E.C.1. The course will be held on successive Thursday evenings at 6.30 p.m., beginning on 23 October. The fee for the course is £2 2s.

## DIARY

**Local Sections and Associated Societies**

**29 October. Liverpool Metallurgical Society.** Visit to John Summers and Sons, Ltd., Hawarden Bridge Steelworks, Shotton.

**30 October. Sheffield Local Section.** Symposium on "Vacuum-Melting". Short talks by three invited speakers, followed by a general discussion. (The University, St. George's Square, Sheffield 1, 2-5.30 p.m.)

**30 October. Southampton Metallurgical Society.** Evening visit to Pirelli General Rolling Mill.

**4 November. Oxford Local Section.** "Alloys of Iron with the Interstitial Elements", by Professor W. Hume-Rothery. (Cadena Café, Cornmarket Street, Oxford, at 7.0 p.m.)

**5 November. Manchester Metallurgical Society.** "Temperature Measurement", by J. A. Hall. (Manchester Room, Central Library, Manchester, at 6.30 p.m.)

**6 November. East Midlands Metallurgical Society.** "Titanium—A Broad Survey", by P. L. Teed. (College of Art, Green Lane, Derby, at 7.30 p.m.)

**6 November. Leeds Metallurgical Society.** "Aluminium Bronzes", by C. V. Wilson. (Lecture Room C, Chemistry Wing, The University, Leeds 2, at 7.15 p.m.)

**6 November. London Local Section.** "Experimental Features of Investigations with Radioactive Materials", by Professor J. G. Ball. (The Royal School of Mines, London, S.W.7, at 7.0 p.m.)

**10 November. Scottish Local Section.** "The Practical Application of Cathodic Protection in the Marine Field", by J. K. H. Tait and R. J. Thubron. (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow C.2, at 6.30 p.m.)

**11 November. South Wales Local Section.** "Geochemical Methods of Mineral Exploration", by Dr. J. S. Webb. (Royal Institution, Swansea, at 7.0 p.m.)

**12 November. Liverpool Metallurgical Society.** "The Gas Cutting of Metal Plates", by Dr. L. C. Bannister. (Joint Meeting with the Institute of Welding, Liverpool Branch.) (Picton Library, Liverpool, at 7.0 p.m.)

**13 November. Birmingham Local Section.** "Steels for Extrusion Tools", by F. Rodgers. (College of Technology, Gosta Green, Birmingham 4, at 6.30 p.m.)

**13 November. Southampton Metallurgical Society.** "Recent Developments in Magnesium-Base Alloy", by D. J. Whitehead. (Southampton University, at 7.15 p.m.)

**19 November. Manchester Metallurgical Society.** "Vacuum Melting", by H. C. Child. (Manchester Room, Central Library, Manchester, at 6.30 p.m.)

**20 November. North East Metallurgical Society.** "Gem Stones", by T. Jones. (Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, at 7.15 p.m.)

**20 November. Sheffield Local Section.** "Chromium and Its Alloys", by E. A. Brandes. (Engineering Lecture Theatre, University Buildings, St. George's Square, Sheffield 1, at 7.30 p.m.)

**21 November. London Local Section.** Annual Informal Dinner. (The Horse Shoe Hotel, Tottenham Court Road, London, 6.30 for 7.15 p.m.)

**27 November. Birmingham Local Section.** "Corrosion and the Microstructure", by Dr. C. Edleau. (Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, at 6.30 p.m.)



# FOUR IMPORTANT METALS BOOKS

from the American Society for Metals

## **C**REEP AND RECOVERY

### **BEST SELLER**

"The utmost in metalworking precision is found in the 'heart' of a jet engine. Disks, mounted on the compressor, must withstand tremendous stresses created by fantastically high temperatures. An error in the amount of heat expansion to expect can turn a jet engine into a disfigured mass of molten metal."

Creep and Recovery deals authoritatively with this interesting and fascinating aspect of metals—changes in dimension under stress and removal of residual stress. Metallurgists, Engineers, Designers, solid state Physicists, and Chemists will find this assembly of the most recent experiments and thoughts on recovery and creep to be invaluable. These masterful papers, extremely well-supplemented with graphs, tables, charts, and photomicrographs, speak with authority and conviction in fourteen different areas of the subject matter. All the knowledge and experience of twenty-two authorities is brought to you in this easily-read, hard-bound edition—a bound volume of papers presented at the meeting on "Creep and Recovery" in Cleveland, Ohio, 1956.

"The Concept of Creep", "The Theory of Creep", "Recovery of Mechanical Properties", and "Creep and Rupture" are only a few of the papers expertly offered in this beautifully bound 6½ x 9½, 372 page book. Never will you find more current material on recovery and creep. Never will you profit more by the experience of such outstanding authors. Act now! Fill in the coupon below. You'll be glad you did!

**\$7.50**

## **D**UCTILE CHROMIUM

If you produce, extract, test, fabricate, design, or use metals in any way, this report of 49 experts on chromium can give you the most up-to-date and accurate information available today. Entirely new fields of usefulness for chromium and its alloys are forecast in this well-illustrated volume of proceedings at the important conference on Ductile Chromium co-sponsored by the Office of Ordnance Research, U.S. Army, and the American Society for Metals.

More than twenty years of intensive research in the United States, Europe and Australia have been devoted to the development of chromium-base alloys for high temperature service. Learn of the significant work on the extraction, fabrication and properties of a metal that is a most promising base for new alloys of superior oxidation resistance and strength at elevated temperatures.

The book's 27 chapters are presented in five sections. Section 1 provides a general review of research on chromium. Section 2 deals with the production of chromium metal. Section 3 discusses ductile chromium metals, with Section 4 devoted to the effect of gas on chromium metal, and Section 5 reports on high-chromium alloys.

Here is an opportunity for you to explore the many new applications for chromium. Be an authority on ductile chromium—over one million tons of chromite ore are consumed annually in the United States! Take advantage of this chance to learn what 49 authorities know about this increasingly important metal. Send for Ductile Chromium with the coupon below.

**\$8.50**

## **E**FFECT OF RESIDUAL ELEMENTS

Learn the importance of impurities in metals! Strangely enough, as this new authoritative book explains, if absolutely pure metals could and were to be substituted for the technical grades currently in use, the metal fabrication industries would be faced with many new and difficult problems! Learn how "Trace Elements" strangely influence mechanical properties and crystal growth of metals. Learn how these impurities influence the strength and ductility of metals!

In this review of fundamental considerations of residual elements, the authors expertly write of the effects these elements have on aluminum, magnesium, copper, nickel, steel, titanium, zirconium, molybdenum, and chromium. Learn how these metals are affected by residual elements. Learn how residual elements, produce favorable qualities and, just as frequently, adverse qualities! Attractively bound in red cloth and consisting of 217 pages, this book brings to you the up-to-date reports of five authorities. Easy to read and well-supplemented with charts, graphs, tables, and photographs, it will become a ready reference for designers, engineers, metallurgists and others whose job it is to know metals.

Make the knowledge of these experts your knowledge. Give yourself the advantage of being well-read on metals. Be capable of answering questions that before were only asked of others. Send today for *Effect of Residual Elements on the Properties of Metals*.

**\$4.00**

## **F**ATIGUE DUR- ABILITY OF CAR- BURIZED STEEL

What factors determine fatigue durability in carburized steel? Why do some carburized steels withstand more stress than others? You can find out in this just-off-the-press book *Fatigue Durability of Carburized Steel*.

Five authorities establish as their goal a better understanding of the interrelation of factors that determine fatigue durability. They state their goal clearly, describe the research and testing accomplished and finish with a declaration of definite conclusions. This is the story of a question and an elusive, but finally captured, answer.

The book is divided into five sections to enable thorough coverage of the subject matter. Beginning with a review of prior efforts, dating as far back as 1860, the authors smoothly and capably document each phase of the search for a better understanding of factors influencing fatigue durability.

For men who specify, design, produce, or use components of carburized steel, *Fatigue Durability of Carburized Steel* gives valuable information and numerous enlightenments that will aid in determining the most effective applications. As a reference, you will reach for it again and again. Help yourself to a more comprehensive understanding of *Fatigue Durability of Carburized Steel*. Read this up-to-the-minute account of fatigue durability that will give you sound reasons for selecting or using particular grades of carburized steel. Increase your sphere of influence and general knowledge of metals by sending in the coupon below.

**\$4.00**

## BE AN AUTHORITY

How many technical books do you read? How many technical books have you read in the past year? How many books have you added to your reference library?

Wherever you work, whatever you do, your success is measured by your knowledge of your job. If your knowledge is current, and consistently upgraded and expanded, you are eligible for promotion.

The Technical and Engineering Book Information Service of ASM can help you to increase your sphere of influence through the reading of technical books. Take advantage of the wealth of authoritative information made available to you. Start today to gain a more comprehensive understanding of metals. Start today to be an authority!

**DON'T FORGET TO ORDER  
THE NEW CATALOG  
OF TECHNICAL BOOKS**

## MAIL THIS COUPON TODAY!

- FOR THE BOOKS OF YOUR CHOICE
- FOR THE NEW FALL CATALOG
- FOR MORE INFORMATION

### ASM Technical and Engineering Book Information Service

7301 Euclid Avenue, Dept. E., Cleveland 3, Ohio

Please Mail ..... copy(s) of:

Ductile Chromium—\$8.50 ☐

Creep and Recovery—\$7.50 ☐

Fatigue Durability of  
Carburized Steel—\$4.00 ☐

Effect of Residual  
Elements on the

Properties of Metals—\$4.00 ☐

Bill my firm ☐

Bill me ☐

Or enclosed find \$.....

Bank Note ☐

International Postal Order ☐

Also send me the free new Catalog of ASM Books ☐

Name ..... Title .....

Company .....

Street .....



# APPOINTMENTS VACANT

**APPLICATIONS** are invited for posts on the scientific staff of this Research Company. Successful candidates will be appointed initially to assist one of the Senior Metallurgists, but will have specific responsibility for a research project, and will be helped by assistants. Superannuation. Honours degree. Write stating age, salary required to: The Secretary, British Oxygen Research & Development, Ltd., Deer Park Road, London, S.W.19.

## COLLEGE OF TECHNOLOGY, BIRMINGHAM

(Designated College of Advanced Technology)

### DEPARTMENT OF METALLURGY

Applications are invited for the post of SENIOR LECTURER in METALLURGY.

Salary Scale—Senior Lecturer (Men) £1350 × £50—£1550.  
(Women) £1080 × £40—£1240  
(Plus equal-pay increment).

In fixing the commencing salary, account may be taken of industrial, professional or research experience up to the maximum of the scale.

Further particulars and forms of application from the Registrar, College of Technology, Gosta Green, Birmingham 4, on receipt of stamped addressed foolscap envelope. Applications to be received within 18 days of this advertisement. Please quote "O".

K. R. PILLING, Clerk to the Governing Body.

**D.S.I.R.** National Physical Laboratory, Teddington, requires Assistant Experimental Officer or Experimental Officer for work on determination of small traces by novel methods of analysis. Work requires initiative and exactitude. Experience of wide range of metallurgical analysis including modern physical methods. Quals. G.C.E. (Advanced) in 2 science or a science and maths. subject, but over age 22, pass degree, H.N.C. in Chemistry, Physics, or Metallurgy or equiv. quals. Post unestablished but prospects of establishment through Civil Service Commission. Salary:—E.O. £970—£1190 (men). A.E.O. £385 (age 18)—£850 (men). 5-day week. Women's scale in accordance with Equal Pay Scheme. Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting F.587/8A. Closing date 15 October 1958.

**METALLURGICAL ENGINEER** required by organization in Leicestershire. Successful applicant will be required to advise on metallurgical problems and preferably finishing processes, including plating, polishing and painting, &c. Duties will include occasional visits to engineering firms throughout the country. Membership of professional institution and ability to work on own initiative essential. Good salary and superannuation under F.S.S.U. Send full details including age, qualifications, experience, and present salary in confidence to Box No. 443, The Institute of Metals, 17 Belgrave Square, London, S.W.1.

## METALLURGICAL RESEARCH

THE MOND NICKEL CO. LTD., is expanding its Development and Research Department Laboratory at Acton, London, N.W.10, and invites applications from Physical Metallurgists for posts as Senior Investigators on the research staff.

The work involves primarily long-term research investigations of the platinum-group metals, particularly studies of the constitution and properties of new alloys and the development of powder-metallurgically produced materials. Publication of results is encouraged. Preference will be given to University-trained graduates with post-graduate research experience.

Salary will be in accordance with experience and qualifications. Pension and assurance schemes are in operation and, in appropriate cases, assistance can be given for housing. Applications, which will be treated in confidence, should give details of age, qualifications, and experience and be addressed to The Manager, Development and Research Department, The Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W.1. Please mark envelopes "Confidential P.M.5."

## WELDING RESEARCH AND DEVELOPMENT LABORATORY

A vacancy has arisen for

### AN EXPERIENCED GRADUATE METALLURGIST

who is required for research and development work on problems associated with the weldability of a wide range of materials which may have applications in Steam, Gas, and Water Turbines and Nuclear Reactors.

Applicants should have had at least three years' general metallurgical experience, and some knowledge of welding problems would be an advantage.

A vacancy also exists for

### A WELDING ENGINEER

to undertake development work on new welding processes and on the application of existing processes to the production welding of components used in Steam, Gas, and Water Turbines and Nuclear Reactors.

Applicants should hold a degree or its equivalent and have had some experience in the problems outlined above.

Please write, giving details of education, qualifications, and experience to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. JM 1814K.

## ENGLISH ELECTRIC